The Effect of Nitrification Inhibitors on Nitrogen Use Efficiency in Drip and Furrow Irrigated Cotton

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ABSTRACT

The use of nitrification inhibitors delays the conversion of ammonium fertilizers to the nitrate form and has the potential to increase nitrogen use efficiency in irrigated agriculture. Two field experiments were conducted at the Maricopa Agricultural Center in 1986 to evaluate the effect of two nitrification inhibitors (N-Serve and an experimental compound, ACP) on the growth, yield, nitrogen uptake, and fertilizer use efficiency obtained by growing cotton using buried-drip and furrow irrigation. ^{15}N labeled ammonium sulfate was applied with and without nitrification inhibitors at the beginning of the season. Whole plant samples were taken at the end of the season to determine N uptake efficiency. No significant differences in growth, lint yield or N uptake efficiency were detected due to the application of either inhibitor. The conditions where nitrification inhibitors might improve nitrogen use efficiency in furrow irrigated cotton production are discussed.

INTRODUCTION

The use of nitrification inhibitors offers the opportunity to delay the conversion of ammonium (NH_4) fertilizers to nitrate (NO_3) favoring the retention of the immobile ammonium form near the site of application. This could result in an increase in the amount of applied nitrogen (N) taken up by the plant and a decrease in the amount of fertilizer nitrogen remaining in the soil in the mobile nitrate form which is susceptible to leaching losses.

Past experiments with nitrification inhibitors in Arizona have shown little advantage of the inhibitors in increasing crop yields except on very sandy soils such as the Superstition sand on the Yuma Mesa. However, evaluating the effectiveness of nitrification inhibitors on the basis of their effect on final yield alone may not give a true indication of their potential to increase nitrogen use efficiency in irrigated agriculture. The use of such products could become increasingly important as environmental protection becomes more stringently enforced.

The use of labeled nitrogen fertilizer allows accurate determination of the uptake efficiency of applied nitrogen with and without nitrification inhibitors.

Two field experiments were conducted at the Maricopa Agricultural Center, 30 miles southwest of Phoenix, Arizona, in 1986 to determine the effect of two nitrification inhibitors on the growth, yield, nitrogen uptake, and fertilizer use efficiency obtained by growing cotton using buried drip and furrow irrigation.

METHODS

EXPERIMENT 1: BURIED DRIP IRRIGATED COTTON

Upland cotton (Deltapine 61) was planted on March 27 and irrigated up on April 1. The row spacing used was 40 inches. Irrigation water was applied through a buried drip irrigation system using Chapin Twin Wall III, 14 mil drip tubing placed 8 inches below the surface of each planting bed. The soil was a Casa Grande sandy loam with an initial nitrate-N content of 6.1 ppm in the surface 18 inches. A total of 56.6 inches of irrigation water was applied with applications scheduled using the Crop Water Stress Index. A total of approximately 30 lbs nitrate-N/acre was applied in the irrigation water.

On May 15 solutions of 1.5 A% ^{15}N $(NH_4)_2SO_4$ containing 6000 mg of total nitrogen (53 lbs N/acre) were applied to one meter miniplots within a single row of larger 4 row plots. The nitrification inhibitor treatments applied with the labeled nitrogen solutions were: 1) 0.25 lbs/acre N-Serve, 2) 0.188 lbs/acre ACP, 3) 0.25 lbs/acre ACP, and 4) a control with no nitrification inhibitor. 'N-Serve' is the tradename for the compound nitrapyrin and 'ACP' is the product name of an experimental compound produced by the American Cyanamid Corporation.

The treatments were replicated three times in corresponding plots within a larger drip irrigation experiment. Plants were at the 4-5 leaf stage of growth at the time of nitrogen application. The solution was applied by making a trench 8 inches deep and placing the solution within 1 inch of the drip tubing. This was to simulate an early-season application of nitrogen through the irrigation system as would be done under normal commercial conditions. The total nitrogen applied to the miniplots was the 53.4 lbs labeled N/acre as no other nitrogen fertilizers were applied during the remainder of the season. Nitrification inhibitor treatments were made at this relatively early point in the growing season for two reasons. First, root damage would be minimal at this time. Second, applications of nitrogen this early in the season would represent the worst case situation for nitrogen loss through leaching and/or denitrification and hence would provide the most favorable conditions for demonstrating a beneficial effect of a nitrification inhibitor with drip irrigation. At the time of nitrogen application, the miniplots were thinned to a uniform stand of 5 plants per meter (20,200 plants per acre). Throughout the growing season, petiole samples were analyzed for nitrate-N content to determine the overall N status of the plants.

On September 9, the above ground portion of the five plants within each miniplot was harvested and separated into four plant parts as follows: 1) seed cotton, 2) burrs, 3) leaves, and 4) stems + petioles + squares. Any unopened bolls present were oven dried at 60° C and separated into seed cotton and burr components. The four component plant parts were oven-dried, weighed, ground, and subsampled for total kjeldahl nitrogen analysis and ^{15}N determination by mass spectrometry.

EXPERIMENT 2: FURROW IRRIGATED COTTON

Upland cotton (Deltapine 90) was planted on April 10 in beds using standard 40 inch spacing. A total of 58 inches of irrigation water was applied during the season with applications scheduled by monitoring of the Crop Water Stress Index. A total of 185 lbs of unlabeled fertilizer N/acre was applied during the growing season. The soil was a Casa Grande sandy clay loam. On May 21 labeled nitrogen solutions were applied in the same manner as described in Experiment 1 except that the 0.188 lb/acre ACP treatment was omitted. All treatments were replicated three times. The cotton was at the two to three leaf stage when the labeled fertilizer solutions were applied. The miniplots were located in the middle of a ten acre field in which there were no other experimental treatments or conditions imposed. As in Experiment 1, petiole samples were taken periodically to monitor the nitrogen status of the plants throughout the growing season.

RESULTS AND DISCUSSION

Results of petiole analyses indicated that for the drip irrigated cotton (Experiment 1), the nitrogen levels in the plant throughout the growing season were in the 'Adequate' but not 'Excessive' range at all times. Plants grown under drip irrigation were characterized by moderate height (3 to 4 ft.),extensive branching, and heavy fruiting along the entire height of the plant. In contrast, nitrate levels in the furrow irrigated cotton (Experiment 2) were consistently in either the 'Excessive' range or in the upper portions of the 'Adequate' range for cotton. These plants showed characteristics of rank growth including very tall plants (6 to 7 ft.), poor boll set and pronounced defoliation in the lower canopy, and excessive boll load at the top of the plant.

The average lint yields, total N uptake, % N taken up from the tracer, and the % N in the plant from the tracer for both experiments are listed in Table 1. The application of nitrification inhibitors had no significant effect on any of these parameters in both experiments at the 0.05 level of probability. Lint yields, and the two measurements of N uptake efficiency were consistently higher in the drip irrigated cotton experiment. This was to be anticipated due primarily to the more precise application of water under this method of irrigation. A well managed drip irrigation system probably offers the best control of water leaching below the root zone. As such there was apparently no advantage in using the nitrification inhibitors where leaching losses of nitrate-N are minimized. It is assumed that nitrogen applied during the portion of the growing season when fertilizer is normally added, (square stage through full flower stage) would have even less potential for leaching than the very early applied nitrogen used in this experiment.

Table 1. Average lint yields, total N uptake, % N taken up from a tracer, and % N in the plant from a tracer in upland cotton receiving various nitrification inhibitor treatments under drip and furrow irrigation.

Experiment 1: Drip Irrigated Cotton

Treatment	Lint Yield	Total N Uptake	% N taken up from tracer	% N in plant from tracer
	---- gms/plot ----		---- percent ----	
Control	324	22.9	42.5	11.8
0.25 N-Serve	305	20.1	39.8	11.9
0.188 ACP	331	23.2	34.6	9.8
0.25 ACP	257	19.2	33.3	10.7
L.S.D. .05	NS	NS	NS	NS

Experiment 2: Furrow Irrigated Cotton

Treatment	Lint Yield	Total N Uptake	% N taken up from tracer	% N in plant from tracer
	---- gms/plot ----		---- percent ----	
Control	178	19.8	23.3	7.1
0.25 N-Serve	210	19.6	21.4	6.7
0.25 ACP	213	20.3	25.0	7.3
L.S.D. .05	NS	NS	NS	NS

The lower N uptake efficiency levels in the furrow irrigated cotton were probably a result of several factors. Compared to drip irrigation, greater quantities of water are applied in a single irrigation event with furrow irrigation which could result in greater overall leaching losses of nitrate-N. Also the high to excessive levels of petiole-nitrogen measured in the furrow irrigated cotton suggests that a greater dilution of the labeled N occurred from soil and fertilizer N in this experiment resulting in a lower N uptake efficiency. Under these conditions it is not surprising that the use of a nitrification inhibitor did not have a significant effect on N uptake efficiency. The potential for a beneficial effect of nitrification inhibitors in furrow irrigated cotton would be better evaluated under conditions where the nitrogen applied more closely equaled the nitrogen needs of the crop.

There appeared to be no consistent difference in the total uptake of N in the drip irrigated vs furrow irrigated cotton. These results suggest that cotton will absorb up to a fixed quantity of nitrogen per unit area and that the efficient partitioning of dry matter into lint is greatly affected by the presence of excessive levels of available N during the growing season. This is further evidence that excessive nitrogen was present in the furrow irrigated experiment.

Summary

Two field experiments were conducted at the Maricopa Agricultural Center to determine the effect of various nitrification inhibitors on the growth, lint yield, total N uptake, and N uptake efficiency for upland cotton under two irrigation systems. Labeled ammonium sulfate solution with and without nitrification inhibitors were applied to miniplots in one field with buried drip and another with furrow irrigation. No improvement in the growth or N uptake efficiency parameters were detected when nitrification inhibitors were applied. In the drip irrigated experiment, this was attributed to the efficiency with which water can be applied with this irrigation delivery system although other conditions would have favored a beneficial response to the use of nitrification inhibitors. In the furrow irrigated experiment there was also no significant improvement in growth, lint yield, or N uptake efficiency with the use of nitrification inhibitors. This was attributed largely to the dilution of the labeled nitrogen applications with what appeared to have been excessive amounts of available N provided as supplemental fertilizer throughout the season. Future work under furrow irrigated conditions would be needed to determine whether nitrification inhibitors could effectively increase nitrogen use efficiency when adequate rather than excessive levels of nitrogen are provided to the cotton crop.